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Title:

Phase Stability Requirements for the SNS Reference System Distribution

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Phase Stability Requirements for the SNS Reference System Distribution

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The purpose of this note is to describe how the phase stability requirements for the SNS reference system will be met. In this note only the 755 MHz distribution system will be discussed since the same methods will be used in the 355 MHz system where the requirements are either the same or less stringent.

This note will only discuss phase changes due to temperature variations. There are other mechanisms for phase drift such as source noise or pressure variation in rigid line or phase drift in the down converting mixer, but they will not be discussed here.

It is useful to begin with the basic equation for calculating phase drift in a transmission system. It is:

$$\Delta\theta = \frac{\tau_{cd} \cdot L \cdot \Delta T \cdot 360 \cdot f}{c \cdot v_{prop} / 100} \qquad (1)$$

$\Delta\theta$: Phase change (deg)
τ_{cd}: Expansion coefficient of the material (ppm/°C)
L: Line length (m)
ΔT: Temperature change (°C)
f: Transmission frequency (MHz)
c: Speed of light (m/s)
v_{prop}: Propagation velocity of line (%c)

The equation can also be used to calculate an allowed temperature variation for a specified phase change.

There are six segments of the distribution system where phase drift can occur and cause a flawed measurement (and subsequent mis-control) of the cavity phase. Figure 1 shows a section of the distribution system and the numbered segments that will be discussed.

1. This is the 755 MHz (LO) distribution line that will be placed in the tunnel. The phase requirement is that the line be stable to 0.1° of phase at 755 MHz (0.367 ps), because a phase drift at 755 will correspond directly to a phase drift at the 50 MHz down converted cavity signal. The line length is 320 meters and the medium is 3 1/8" rigid copper (τ_{cd} = 16.6, v_{prop} = 99.8 %c), with these values eq. (1) shows that the allowed temperature variation in the line is 0.02°C. It would be impossible to control the temperature so tightly in a line this length so the line is broken into 100 ft (30.5 m) sections with expansion joints at each section. The expansion joints are firmly mounted to the ceiling of the tunnel and thus provide a fixed phase plane every 100 ft. In essence this eliminates the cumulative expansion in the line. Using this scheme the

length in eq. (1) can effectively be changed to 30.5 meters and the resulting allowed temperature variation is 0.22 °C. A temperature control system is required for this line and the specified tolerance is 0.1 °C.

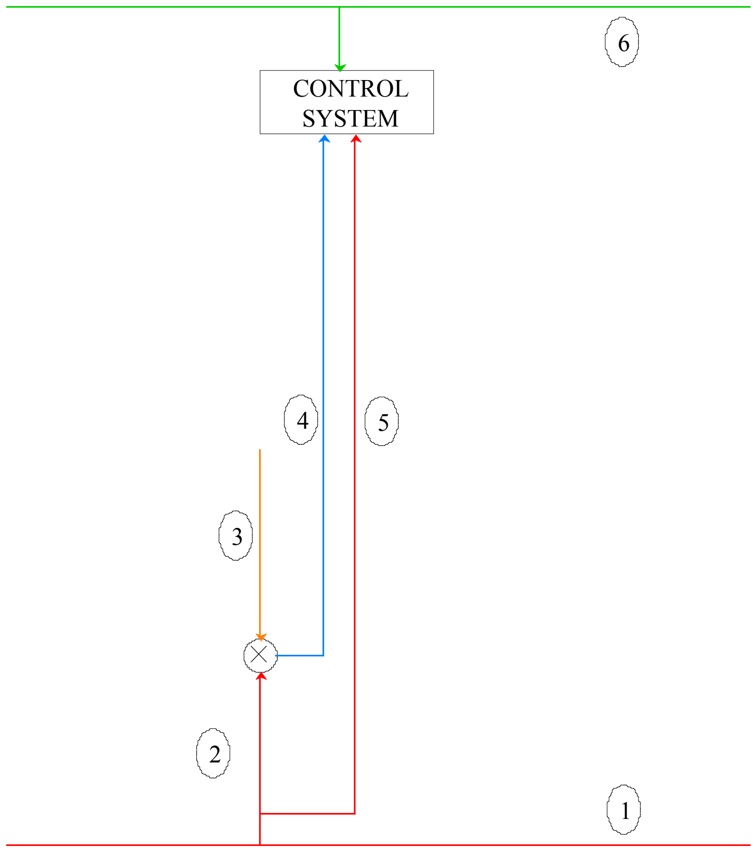

Figure 1. Numbered segments of SNS distribution system.

2. This is a 1 meter section of semi-rigid co-ax (3/8" Heliax) used to take the LO (755 MHz) signal from the rigid line to the mixer, which is also placed inside the heat blanket. The line used is temperature compensated and has a coefficient of expansion of 5.6 ppm and a propagation velocity of 88 %c. Since this section is temperature controlled to the same tolerance as the rigid line, its phase change at 755 MHz will be at most 0.000577° and can effectively be ignored.

3. This is a 3 meter section of Heliax used to transport the cavity signal at 805 MHz to the mixer. Again phase must be controlled at 805 MHz since phase transfers directly to the 50 MHz IF output of the mixer. A phase tolerance of 0.1° at 805 MHz corresponds to a temperature variation of 5.42 °C for this line.

4. This is a 30 meter section of Heliax used to transfer the 50 MHz down converted cavity field signal to the control system located outside of the tunnel. Its phase tolerance requirement is 0.1° at 50 MHz (5.56 ps). This corresponds to an allowed temperature variation of 8.72 °C in the tunnel chase as well as the upstairs gallery.

5. This is a 30 meter section of Heliax used to bring a sample of the LO signal to the control system. This signal has three uses in the control system. First it is used to downconvert the Beam, Forward, and Reflected control signals. Second it is used to upconvert the cavity control signal. Finally, it is used to provide a phase lock to a 2.5 MHz signal (6) distributed to every control system in the gallery. The phase drift allowed in this signal is 0.1° at *50 MHz* (5.56 ps). The reasons that 50 rather than 755 MHz is used are as follows. In the first use (Beam, Forward, and Reflected down conversion) accuracy beyond 0.1° at 50 MHz is not required for the processes to work. In the second use (up conversion of the cavity control signal) 0.1° at *755 MHz* is required but since the conversion takes place *inside* the control loop any phase drift will be reduced by a factor equal to the loop gain which will be very large especially for low frequency disturbances (like phase drift), so in this case 0.1° at 50 MHz is again sufficient. The final use is as a phase reference used to lock a 2.5 MHz distributed signal. Each control system will create a 40 MHz an a 50 MHz clock from this 2.5 MHz signal and the highest frequency of these clocks (50 MHz) must be stable to 0.1°. Consequently the locking reference must only be stable to this tolerance, so again the specification is 0.1° at 50 MHz. Thus for every use of this LO feed the most stringent tolerance is 0.1° at 50 MHz, consequently the allowed temperature drift is 8.72 °C as in (4) since the lengths are the same.

6. This is a 320 meter Heliax line used to distribute a 2.5 MHz signal to all the control systems for 40 and 50 MHz clock generation. This signal will be phase locked to the LO feed (5) using a D flip-flop. For this reason the allowed phase drift in this line is one half cycle (180°) at 755 MHz (0.662 ns). This corresponds to a temperature variation of 97.5 °C. It should be noted that this error is non-linear. A temperature variation of 50 °C will produce no error since it the 2.5 MHz edge will be within the same half cycle of the 755 signal. However a temperature variation of 100 °C will produce a 0.6° phase change in the 2.5 MHz signal since the edge will jump to the next half cycle of the 755 signal.

The following table summarizes these results.

Line #	Line Freq. (MHz)	Line Length (m)	Phase Control Freq. (MHz)	Phase Drift at Relevant Frequency (°/°C)	Expected Temperature Drift (°C)	Phase Drift (°)
1	755	320 (30.5)	755	0.46	0.1 (controlled)	0.046
2	755	1	755	0.02	0.1 (controlled)	0.000577
3	805	3	805	0.018	1	0.018
4	50	30	50	0.011	2	0.023
5	755	30	50	0.011	2	0.023
6	2.5	320	N/A	N/A	< 97.5	0
					TOTAL:	0.111